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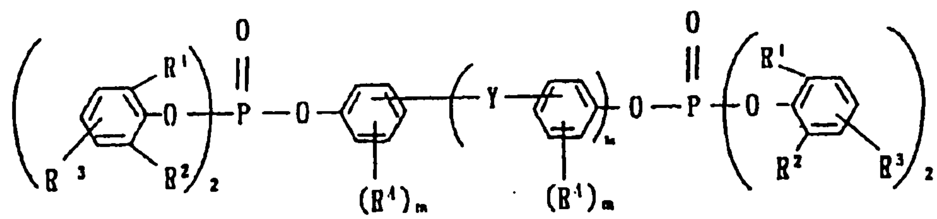
(54) **Crystalline powders of aromatic diphosphates, their preparation and use.**

(57) Crystalline powders of an aromatic diphosphate of the formula (I):



(I)

wherein R^1 and R^2 are, the same or different, a lower alkyl group, R^3 is a hydrogen atom or a lower alkyl group, R^4 is a hydrogen atom or a lower alkyl group, Y is a bonding arm, $-CH_2-$, $-C(CH_3)_2-$, -S-, $-SO_2-$, -CO-, -O- or -N=N-, k is 0 or 1 and m is an integer of 0 to 4.

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to crystalline powders of an aromatic diphosphate and their preparation and use. The aromatic diphosphates are powders of high purity, can improve thermoplastic or thermosetting resins in their flame retardance, thermal stability and moldability and hence are useful as a flame-retardant, antioxidant and plasticizer.

2. Description of the Related Art

In order to impart flame retardance to a thermoplastic or thermosetting resin, a flame-retardant has been added to the resin at a molding process thereof.

Conventional flame-retardants are inorganic compounds, organophosphorus compounds, organohalogen compounds, halogen-containing organophosphorus compounds and the like. Among the above compounds, organohalogen compounds and halogen-containing organophosphorus compounds show a superior flame retardant effect. However, such halogen-containing compounds are pyrolyzed at a molding process of the resin added with the same, thereby generating a hydrogen halide which corrodes a mold used and deteriorates the resin with its color possibly changed. Further, the resultant halide makes a working environment bad. Another problem associated with the compounds is that they generate a toxic gas, e.g., hydrogen halide, which is harmful to human beings, in case of burning caused by a fire, etc.

Halogen-free flame-retardants are inorganic compounds such as magnesium hydroxide and the like. Such inorganic compounds, however, show so little a flame retardant effect that they have to be added in a large amount to obtain a satisfactory result. This leads to degradation of physical properties of the resin itself.

Organophosphorus compounds are widely used as a halogen-free flame-retardant showing a relatively good flame retardant effect. Although triphenyl phosphate (TPP) is well known as a typical organophosphorus compound, it suffers from less heat resistance and rather high volatility.

The organophosphorus compounds showing a relatively low volatility include polyphosphoric esters as disclosed in Japanese Patent Publication Nos. 19858/1976 and 18336/1990. Although these compounds show good heat resistance compared to triphenyl phosphate, they cannot be proof against higher temperature of around 300 °C which is required to mold recently developed high-performance plastics such as engineering plastics or super-engineering plastics. Further, polyphosphoric esters are liquid, and hence lower physical properties of the resin, for example, a thermal deformation temperature.

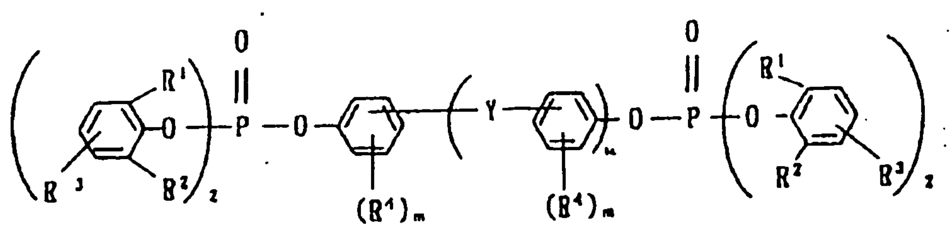
Flame-retardants showing low volatility as well as heat resistance are organic phosphates having an aromatic group bonded with a steric hindrance group at ortho position thereof, as disclosed in U.S. Patent No. 4,134,876. The above organic phosphates are represented by of the following formula:

$M_2PO_4[D\text{-}PO_4\text{-}(M)]_nM$

wherein M is a residue of a monohydric phenol; D is a residue of a dihydroxy phenol; and n is an average value from 1 to 5. All of the organophosphates disclosed in Examples thereof however are mixtures of organic phosphates wherein n is 1 or more. Such mixtures are colored resinous solids, and hence lack moldability when added to a resin.

SUMMARY OF THE INVENTION

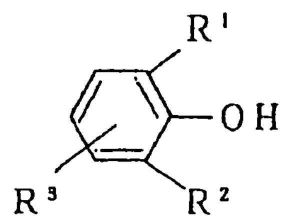
The present invention provides crystalline powders of an organic diphosphate of the formula (I):



(I)

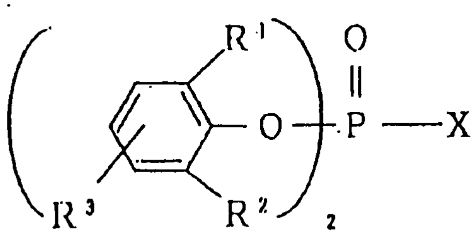
wherein R^1 and R^2 are, the same or different, a lower alkyl group, R^3 is a hydrogen atom or a lower alkyl group, R^4 is a hydrogen atom or a lower alkyl group, Y is a bonding arm, $-CH_2-$, $-C(CH_3)_2-$, -S-, $-SO_2-$, -CO-, -O- or -N=N-, k is 0 or 1 and m is an integer from 0 to 4.

The organic diphosphate (I) can be prepared by reacting an aromatic monohydroxy compound having a group for giving steric hindrance at the ortho position of the formula (II):



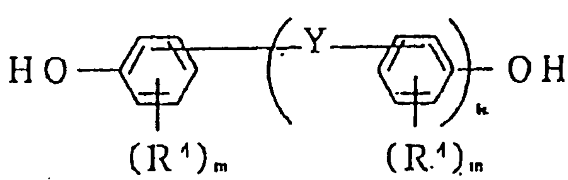
(II)

wherein R^1, R^2 and R^3 have the same meanings as above, with a phosphorus oxyhalide in the presence of a Lewis acid catalyst to obtain a diarylphosphoro halidate of the formula (III):



(III)

wherein R^1, R^2 and R^3 have the same meanings as above, and X is a halogen, and reacting the resultant (III) with an aromatic dihydroxy compound of the formula (IV):



(IV)

wherein R^4, Y, k and m have the same meanings as above in the presence of a Lewis acid catalyst.

The present invention also provides a flame retardant and thermally stable composition comprising crystalline powders of the formula (I) and a thermoplastic or thermosetting resin.

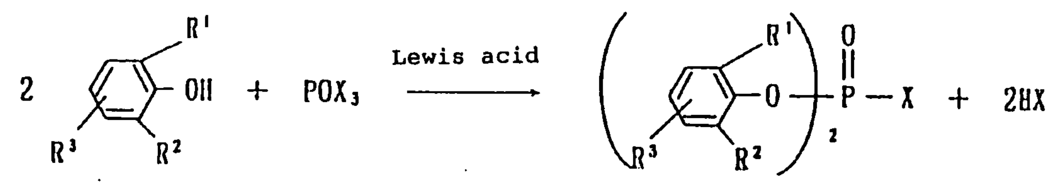
BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1, 2 and 3 show the infrared absorption spectra of Compounds 1, 2 and 3 as obtained by the enbodiments of the present invention, respectively.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

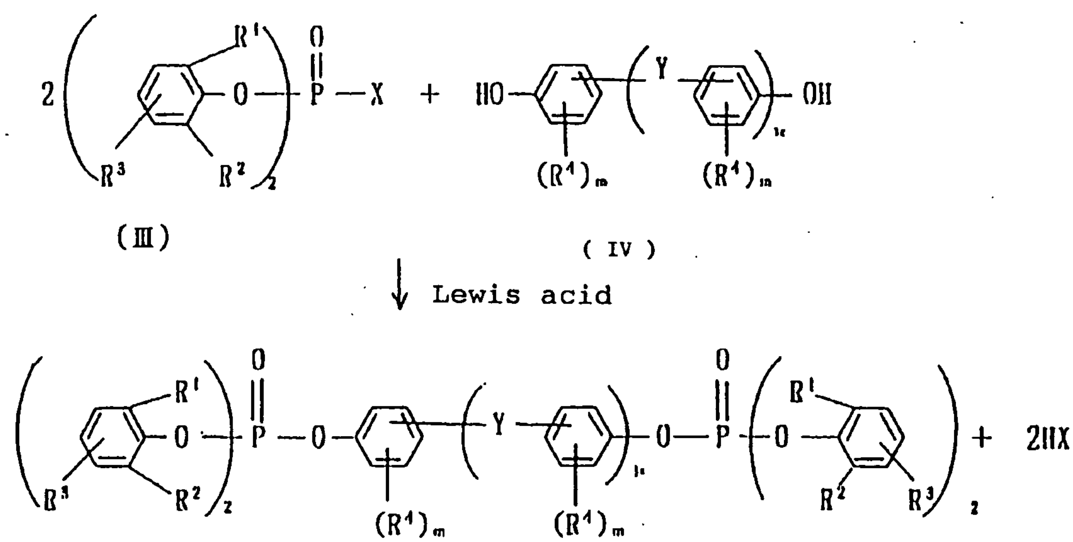
The method for preparing an organic diphosphate (I) according to the present invention is shown in the following schemes:

Step 1



(II) (III)

Step 2



(III) (IV) (I)

The term "a lower alkyl group" used for the symbols R^1, R^2, R^3 and R^4 in the above formulae means a straight or branched chain C_{1-5} alkyl group. Examples of the groups include methyl, ethyl, propyl, isopropyl, n-butyl, isobutyl, tert-butyl, n-pentyl, isopentyl, tert-pentyl, neopentyl and the like, among which methyl is preferable.

Examples of the aromatic monohydroxy compounds (II) used in Step 1 include 2,6-xylenol, 2,4,6-trimethylphenol and the like, among which 2,6-xylenol is preferable. Examples of the phosphorus oxyhalides include phosphorus oxychloride, phosphorus oxybromide, among which phosphorus oxychloride is preferable.

Examples of the aromatic dihydroxy compounds (IV) used in Step 2 include hydroquinone, resorcinol, pyrocatechol, 4,4'-biphenol, 2,2',6,6'-tetramethyl-4,4'-biphenol, bisphenol A, bisphenol S and bisphenol F and the like, among which hydroquinone, resorcin or 4,4'-biphenol is preferable.

Examples of the Lewis acid catalysts used in Step 1 include aluminum chloride, magnesium chloride, titanium tetrachloride, antimony pentachloride, zinc chloride, tin chloride and the like, among which magnesium chloride is particularly preferable. A mixture of two or more of these catalysts may be used.

In Step 2, the catalyst can be utilized as it is in Step 1 but be further added. Preferred catalyst in Step 2 is aluminum chloride. Also, an amine such as trimethylamine or tributylamine may be used in Step 2.

The phosphourus oxyhalide such as $POCl_3$, $POBr_3$ or the like is used in a ratio of at least 0.5 mol equivalent amount with respect to the compound (II). Usually, 1 - 1.2 mol of phosphorus oxyhalide is used per 1 mol of the compound (II). When phosphorus oxyhalide is used in an excess amount, it will give by-product of diarylphosphoro halidate produced which then causes to yield a higher polymerization product at Step 2. On the contrary, if the phosphorus oxyhalide is insufficient, the ratio of the triarylphosphate (by-product) is raised. Anyway, the purity of the objective compound is lowered.

The compound (IV) is used in a ratio of 0.5 mol equivalent amount with respect to the compound (III).

The amount of the catalyst used in Step 1 is more than 0.1 wt. % with respect to the phosphorus oxyhalide, preferably in the range between 0.5 - 2.0 wt. %.

The amount of the catalyst used in Step 2 is more than 0.1 wt. % with respect to the phosphorus oxyhalide used in Step 1, preferably in the range between 0.5 - 5.0 wt. %.

The reaction temperature in Steps 1 and 2 is 50 - 250 °C, preferably 100 - 200 °C. Pressure in the reaction system may be reduced so as to remove hydrogen halide produced in the reaction, thereby accelerating the reaction.

Though a solvent need not necessarily be used in Step 1, it may optionally be used. Examples of the solvents include xylene, toluene, chlorobenzene, dichlorobenzene and the like.

In Step 1, the purity of the product is usually more than 99 %, and hence the product can be used in Step 2 without purification.

After Step 2 is completed, impurities in the product, e.g., catalysts are washed and removed by a conventional method. For example, the product is contacted with an acid solution, for example, hydrochloric acid solution so that impurities are extracted into the aqueous solution. At that time, an organic solvent may be added to the solution for preventing the aromatic diphosphate from becoming solid and for serving as a crystallizing solvent later. The organic solvent preferably dissolves the aromatic diphosphate well at a high temperature while dissolving less at a low temperature. Such a solvent includes toluene, xylene, chlorobenzene, dichlorobenzene or the like, which is in no way limitative to this invention and may be used as a mixture thereof. The temperature for the contact of the product with the acid solution as stated above is from room temperature up to near the boiling point of the solution. The amount of the organic solvent used is not particularly limited so long as the aromatic diphosphate is not crystallized at the temperature for the contact.

The washed mixture may be cooled to precipitate crystals which then are separated by filtration. Alternatively, water content contained or dispersed in the solution may be removed to precipitate crystals which are then separated. The resultant crystals are dried and used without purification, or are washed with a solvent such as water, methanol or ethanol which can hardly dissolve the aromatic diphosphate and dried for use.

The aromatic diphosphate prepared according to the present invention is effective for a thermoplastic resin (except polyester) or thermosetting resin as a flame-retardant, antioxidant and plasticizer, and therefore can endow the resin with flame retardance and thermal stability and improve the moldability of the resin. In addition, properties of the resin are less deteriorated.

Examples of the thermoplastic resins include chlorinated polyethylenes, polyethylenes, polypropylenes, polybutadienes, styrene resins, high-impact polystyrenes, polyvinyl chlorides, ACS resins, AS resins, ABS resins, modified polyphenylene oxides, polymethyl methacrylates, polyamides, polycarbonates, polyphenylene sulfides, polyimides, polyether-ether-ketones, polysulphones such as polyether sulphones, polyarylates, polyetherketones, polyether nitriles, polythioether sulfons, polybenzimidazoles, polycarbodiimides, polymer liquid crystals, composite plastics and the like. Examples of the thermosetting resins include polyurethanes, phenol resins, melamine formaldehyde resins, urea resins, unsaturated polyesters, diallyl phthalate resins and the like. One of the above-mentioned resins may be mixed with one or more of the others for use.

Flame retardant compositions of the present invention may contain various additives such as other kinds of flame-retardants, antioxidant, filler, lubricant or the like.

The kind and amount of the aromatic diphosphate to be used is dependent on the kind and amount of resin, and the flame-retardant required. The aromatic diphosphate is used usually in an amount of 0.1 to 100 parts by weight with respect to 100 parts by weight of the above resin. The aforesaid resin, aromatic diphosphate and any optional additives are mixed and molded by a known method to obtain a flame retardant molding product. The aromatic diphosphate is added, for example, together with a monomer which is to be charged to produce the above resin by bulk polymerization; in the end period of bulk polymerization or at molding process of the resin; or in the form of solution or fluid solution for applying to a surface of resin products such as film or filament.

In terms of workability in preparing the resin composition, a flame-retardant is preferably in a powder

form retardant because of its mixing affinity with the resin. The aromatic diphosphates prepared according to the present invention are crystalline powders of high purity, more than 98 %. The aromatic diphosphate is superior in thermal stability and heat resistance against a high temperature at molding process while properly giving plasticity and hence a good processability even to engineering plastics or super-engineering plastics having a higher performance which require a high temperature to be molded, as stated above.

EXAMPLES

Example 1

2,6-Xylenol (244 g), xylene (20 g), magnesium chloride (1.5 g) were placed in a four-neck flask with a stirrer, a thermometer, a dropping funnel and a condenser connected to a water scrubber. The mixture was heated with stirring. When the temperature of the reaction mixture reached 120 °C, phosphorus oxychloride (153 g) was added by portions over about 2 hours. Hydrogen chloride gas, which was then generated, was led to the water scrubber. After phosphorus oxychloride was added, the temperature of the mixture was gradually raised up to 180 °C over 2 hours to complete the reaction. The yield of the resultant di-(2,6-xylyl)phosphoro chloridate was 99.7 %. The composition ratio and yield of organic phosphorus compounds in the product analyzed by gas chromatography are shown in Table 1. Table 1 also shows results of products obtained in Examples 2 to 4, and comparative examples 1 and 2 to be described below.

TABLE 1

	Aromatic monohydroxy compound (g)	Phosphorus oxyhalide (g)	Lewis acid catalyst (g)	Yield (%)	Phosphorus phosphate ester composition ratio (%)		
					Monoaryl phosphoro dihalodate	Diaryl phosphoro halidate	Triaryl phosphate
Example 1	2,6-Xylenol 244	Phosphorus oxychloride 153	$MgCl_2$ 1.5	99.7	0.0	99.4	0.6
Example 2	2,6-Xylenol 244	Phosphorus oxychloride 153	$AlCl_3$ 1.5	98.3	0.0	99.0	1.0
Example 3	2,6-Xylenol 244	Phosphorus oxybromide 393	$MgCl_2$ 1.5	98.9	0.0	99.5	0.5
Example 4	2,4,6-Tri-methyl-phenol 272	Phosphorus oxychloride 153	$MgCl_2$ 1.5	98.9	0.0	99.7	0.3
Comparative Example 1	Phenol 188	Phosphorus oxychloride 153	$MgCl_2$ 1.5	90.5	14.4	67.0	18.6
Comparative Example 2	3,5-Xylenol 244	Phosphorus oxychloride 153	$MgCl_2$ 1.5	88.6	18.1	68.7	13.2

Example 2

Di(2,6-xylyl)phosphoro chloridate was obtained in the same manner as Example 1, except using aluminum chloride instead of magnesium chloride.

Example 3

Di(2,6-xylyl)phosphoro bromidate was obtained in the same manner as Example 1, except using phosphorus oxybromide (393 g) instead of phosphorus oxychloride (153 g).

Example 4

Di(2,4,6-trimethylphenyl) phosphoro chloridate was obtained in the same manner as Example 1, except using 2,4,6-trimethylphenol (272 g) instead of 2,6-xylenol (244 g).

Comparative example 1

Diphenyl phosphoro chloridate was obtained in the same manner as Example 1, except using phenol (188 g) instead of 2,6-xylenol (244 g).

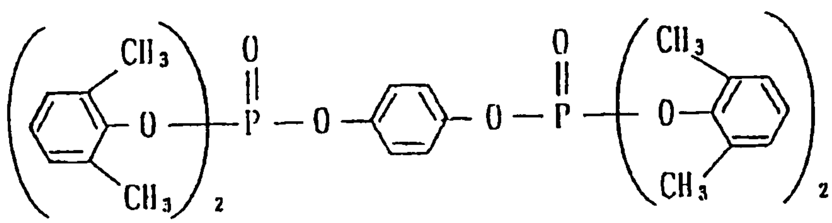
Comparative example 2

Di(3,5-xylyl) phosphoro chloridate was obtained in the same manner as Example 1, except using 3,5-xylenol instead of 2,6-xylenol.

In Examples 5 to 7, di(2,6-xylyl) phosphoro chloridate obtained in the manner of Example 1 was used.

Example 5

Di(2,6-xylyl)phosphoro chloridate (345 g), hydroquinone (55 g), aluminum chloride (1.5 g) were placed in a four-neck flask with a stirrer, a thermometer and a condenser connected to a water scrubber. The mixture was heated and mixed with stirring. The reaction mixture was subjected to dehydrochlorination by raising a temperature thereof up to 180 °C over 2 hours. After matured at the same temperature for 2 hours, the mixture was further matured under a reduced pressure of 200 mmHg for more 2 hours to complete the reaction. Xylene (500 g) and 10 % hydrochloric acid solution (200 g) were added to the reaction mixture. The mixture was stirred, and residual catalyst was removed. Further, the reaction mixture was washed with water and cooled to room temperature with stirring to precipitate crystals. The resultant crystals were separated by filtration, washed with methanol (200 g) and dried at 100 °C under reduced pressure to give crystals, white crystalline powders (326 g, yield 95 %). Gel permeation chromatography revealed that the purity of the obtained crystals was 98.5 %. The crystalline product (this is hereinafter referred to as Compound 1) is represented by the following chemical formula:



Compound 1

Melting point was 168 to 169 °C. Table 2 shows the physical properties (yield, purity and melting point) of the obtained crystalline product as well as those of the products of Examples 6 and 7. IR spectrum of this compound is shown in Fig. 1.

NMR ($CDCl_3$) δ: 2.52(24H,s), 7.51(12H,s), 7.435(4H,d,J=11Hz)

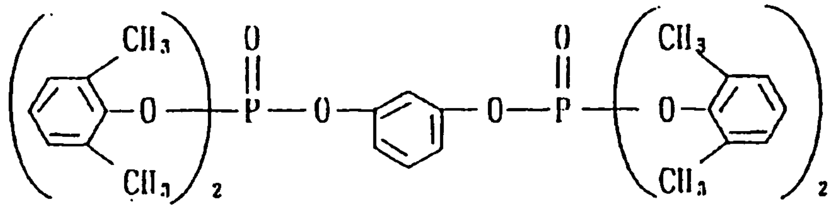
TABLE 2

	Aromatic dihydroxy compound(g)	Bis(2,6-xylyl) phosphoro chloridate(g)	Yield (g)	Yield (%)	Form	Melting Point (°C)	Purity (%)
Example 5	Hydroquinone 55	345	326	95	White Crystalline Powder	168-169	98.5
Example 6	Resorcinol 55	345	330	96	White Crystalline Powder	95-96	99.0
Example 7	4,4'-Biphenol 93	345	355	93	White Crystalline Powder	182-183	98.7

Example 6

White powders of an aromatic diphosphate were obtained in the same manner as Example 4, except using resorcin instead of hydroquinone (this is hereinafter referred to as Compound 2). Compound 2 is

represented by the following formula:



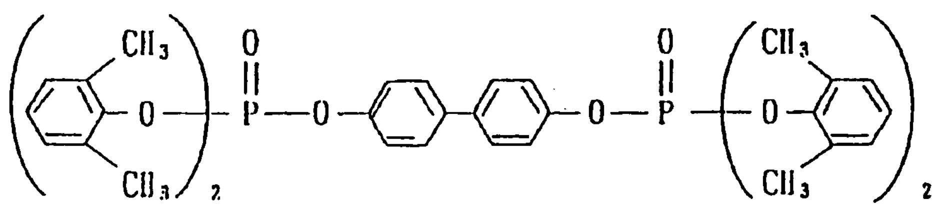
Compound 2

IR spectrum of this compound is shown in Fig. 2.

NMR ($CDCl_3$) δ: 2.27(24H,s), 6.98(12H,s), 7.23(4H,s)

Example 7

White powders of an aromatic diphosphate (this is hereinafter referred to as Compound 3) were obtained in the same manner as Example 4, except using 4,4'-biphenol (93 g) instead of hydroquinone (55 g). Compound 3 is represented by the following formula:



Compound 3

IR spectrum of this compound is shown in Fig. 3.

NMR ($CDCl_3$) δ: 2.42(24H,s), 7.17(12H,s), 7.19(8H,s)

Example 8

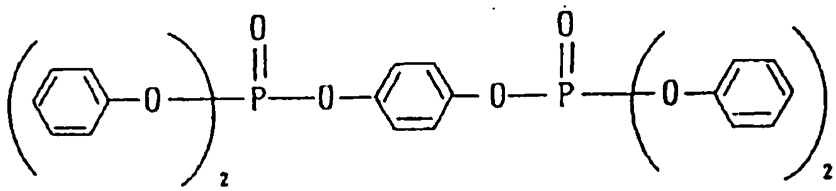
Each 10 parts of the flame-retardants obtained in Examples 5 to 7 were added to a resin comprising 60 parts of poly(2,6-dimethyl-1,4-phenylene)oxide and 40 parts of rubber modified high-impact polystyrene, stirred and subjected to an extruder at 300 °C to obtain a compounding pellet. This pellet was put in an injection molder at 290 to 300 °C to give a test piece for measuring its flame retardance, susceptibility to discoloration, heat deformation temperature, Izod impact strength and tensile strength. Table 3 shows these results as well as those of Comparative example 3 to be described next.

TABLE 3

	Flame-retardant	Flame Retardance	Discoloration	Heat deformation temperature (°C)	Izod impact strength (kg-pcm/cm)	Pulling strength (kg/cm^2)
Example 8	Compound 1	V-0	Not discolored	130	27	650
	Compound 2	V-0	Not discolored	128	26	640
	Compound 3	V-0	Not discolored	131	28	660
Comparative Example 3	TPP	V-2	Discolored	109	12	480
	Compound 4	V-2	Slightly discolored	116	16	510
	Compound 5	V-2	Slightly discolored	110	14	530
	Control	burned	Slightly discolored	133	30	680

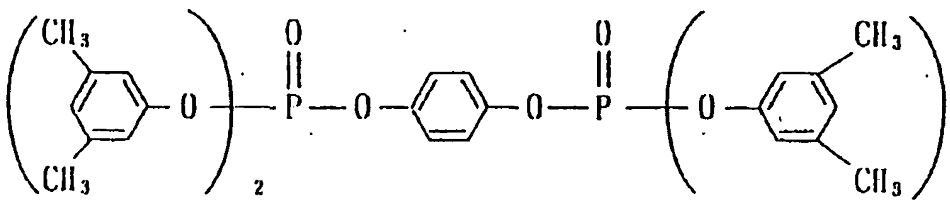
Comparative example 3

A test piece was obtained in the same manner as Example 8, except using, as a flame-retardant, TPP and compounds of the following formulae:



Compound 4

and



Compound 5

Example 9

Each 10 parts of the flame-retardant obtained in Examples 5 to 7 were added to 100 parts of a polycarbonate resin, stirred and subjected to an extruder kept at 280 °C to give a compounding pellet. This pellet was put in an injection molder at 260 to 280 °C to obtain a test piece for measuring its flame retardance, susceptibility to discoloration, heat deformation temperature, Izod impact strength and tensile strength in the same manner as Example 8. Table 4 shows these results as well as those of Comparative example 4 to be described next.

TABLE 4

	Flame-retardant	Flame Retardance	Discoloration	Heat deformation temperature (°C)	Izod impact strength (kg-pcm/cm)	Pulling strength (kg/cm^2)
Example 9	Compound 1	V-0	Not discolored	132	90	620
	Compound 2	V-0	Not discolored	130	88	610
	Compound 3	V-0	Not discolored	133	92	640
Comparative Example 4	TPP	V-2	Discolored	108	79	450
	Compound 4	V-2	Slightly discolored	112	83	480
	Compound 5	V-2	Slightly discolored	111	82	502
	Control	burned	Slightly discolored	134	95	650

Comparative example 4

Comparative example 4 was carried out in the same manner as Example 9, except using TPP with Compounds 4 and 5 each as a flame-retardant to obtain a test piece.

Example 10

Each 10 parts of the flame-retardants obtained in Examples 5 to 7 were added to 100 parts of a polyphenylene sulfide resin, stirred and subjected to an extruder kept at 350 °C to give a compounding pellet. This pellet was put in an injection molder at 330 to 350 °C to obtain a test piece for measuring its flame retardance, susceptibility to discoloration, heat deformation temperature, Izod impact strength and tensile strength. Table 5 shows these results as well as those of Comparative example 5 to be described next.

TABLE 5

	Flame-retardant	Flame Retardance	Discoloration	Melt Flow Rate (g/10min)
Example 10	Compound 1	V-0	Not discolored	24
	Compound 2	V-0	Not discolored	35
	Compound 3	V-0	Not discolored	18
Comparative Example 5	TPP	Collapse of a compounding pellet prevented a preparation of a test piece.		
	Compound 4			
	Compound 5			
	Control	Burned		12

Comparative example 5

Comparative example 5 was carried out in the same manner as Example 10, except using TPP together

with Compounds 4 and 5 as a flame-retardant to obtain a test piece.

Flame retardance

Flame retardance of the test pieces was evaluated by a test method of UL-94, and classified into four stages of V-0, V-1, V-2 and HB.

Susceptibility to discoloration

Discoloration of the test pieces was evaluated by visual test.

Heat deformation temperature

Heat deformation temperature was measured under a load of 18.6 kg/cm^2 in compliance with ASTM D-648.

Tensile strength

Pulling strength was measured in compliance with ASTM D-638.

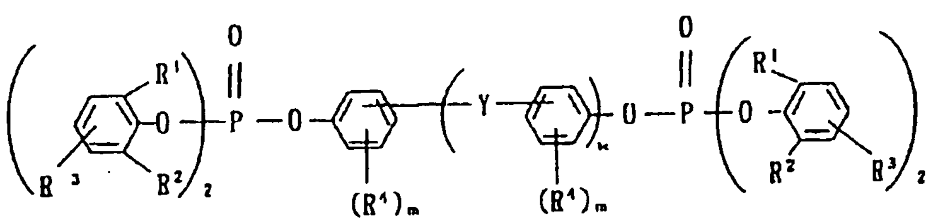
Melt flow rate

Melt flow rate was measured at 330 °C under a load of 5 kg in a manipulation A in compliance with JIS K7210.

As have been described above, according to the present invention, a thermally stable aromatic diphosphate can economically be prepared as crystalline powders of high purity, more than 98 %. The aromatic diphosphate is so superior in workability for preparing the resin composition that the aromatic diphosphate when added to various thermoplastic resins (except polyester) or thermosetting resins can impart flame retardance to these resins. Further, the aromatic diphosphate exhibits a good thermal stability and anti-oxidant action, and is less pyrolyzed at a molding process of the resin, hence causing the resin little coloration and deterioration. As a result, the diphosphate hardly deteriorates the physical properties of the resins. Moreover, the aromatic phosphate gives plasticity even to engineering plastics and super-engineering plastics, which are poor in processability, and hence can remarkably improve moldability of these plastics.

Claims

1. Crystalline powders of an aromatic diphosphate of the formula (I):

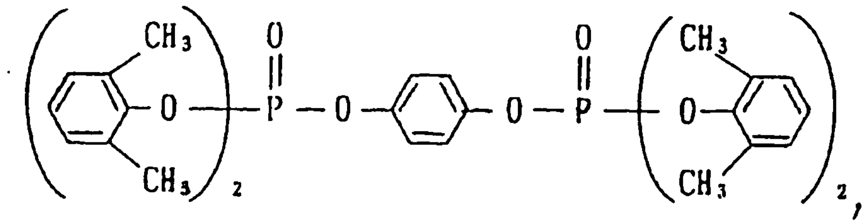


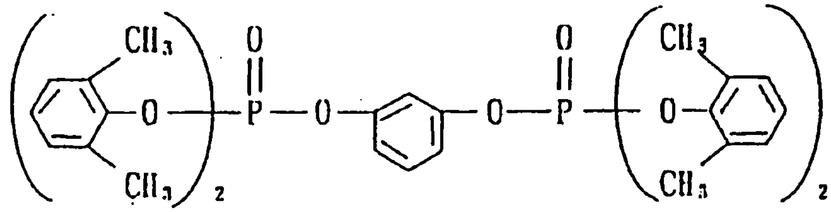
(I)

wherein R^1 and R^2 are, the same or different, a lower alkyl group, R^3 is a hydrogen atom or a lower alkyl group, R^4 is a hydrogen atom or a lower alkyl, Y is a bonding arm, $-CH_2-$, $-C(CH_3)_2-$, -S-, $-SO_2-$, -CO-, -O- or -N=N-, k is 0 or 1 and m is an integer of 0 to 4.

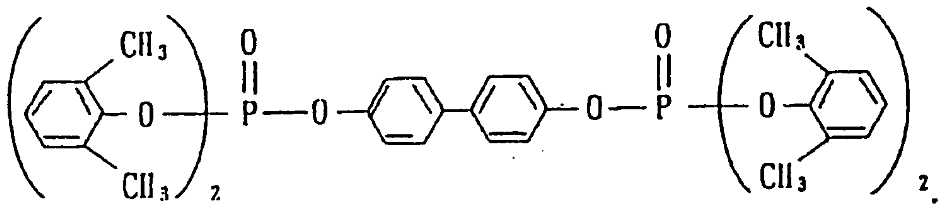
2. The crystalline powders of claim 1 wherein both of R^1 and R^2 are a methyl group, both of R^3 and R^4 are a hydrogen atom, Y is a bonding arm, k is 0 or 1 and m is 1.

3. The crystalline powders of claim 1 wherein the aromatic diphosphate is any one of

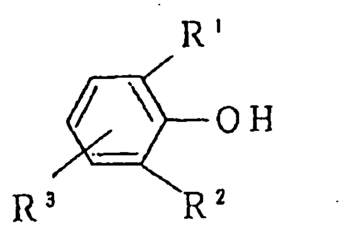




and

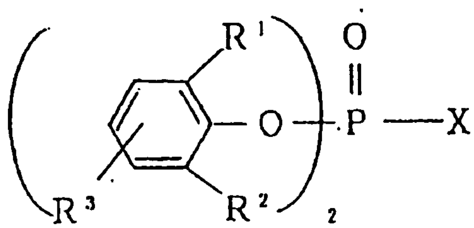


4. The crystalline powders of claim 1 which is obtainable by reacting an aromatic monohydroxy compound of the formula (II):



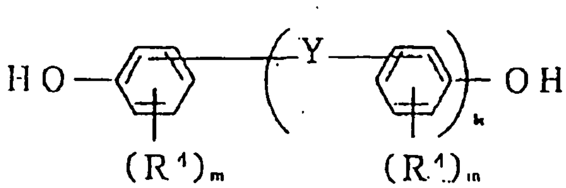
(II)

wherein R^1, R^2 and R^3 have the same meanings as defined in the formula (I), with a phosphorus oxyhalide in the presence of a Lewis acid catalyst to produce a diarylphosphoro halodate of the formula (III):



(III)

wherein R^1, R^2 and R^3 are as defined above and X is a halogen atom, and reacting the compound (III) with an aromatic dihydroxy compound of the formula (IV):



(IV)

wherein R^4, Y, k and m have the same meanings as defined in the formula (I), in the presence of a Lewis acid catalyst.

5. The crystalline powders of claim 4 wherein the Lewis acid catalyst used is magnesium chloride.

6. A flame retardant and thermally stable composition comprising crystalline powders of the formula (I) in claim 1 and a thermoplastic or thermosetting resin.

7. The flame retardant and thermally stable composition of claim 6 wherein the crystalline powders are used in an amount of 0.1 - 100 parts by weight to 100 parts by weight of the thermoplastic or thermosetting resin.

FIG. 1

Compound 1

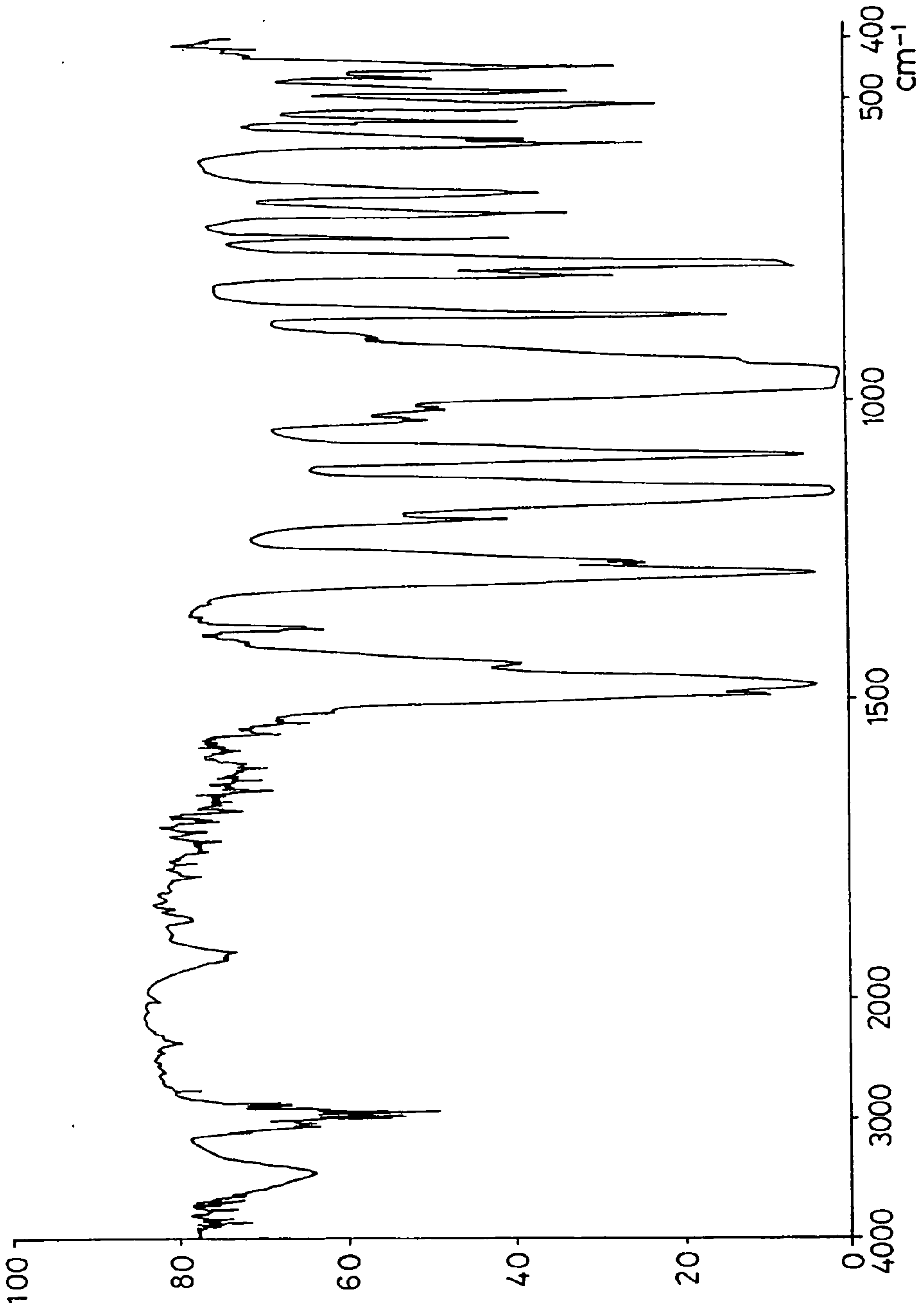
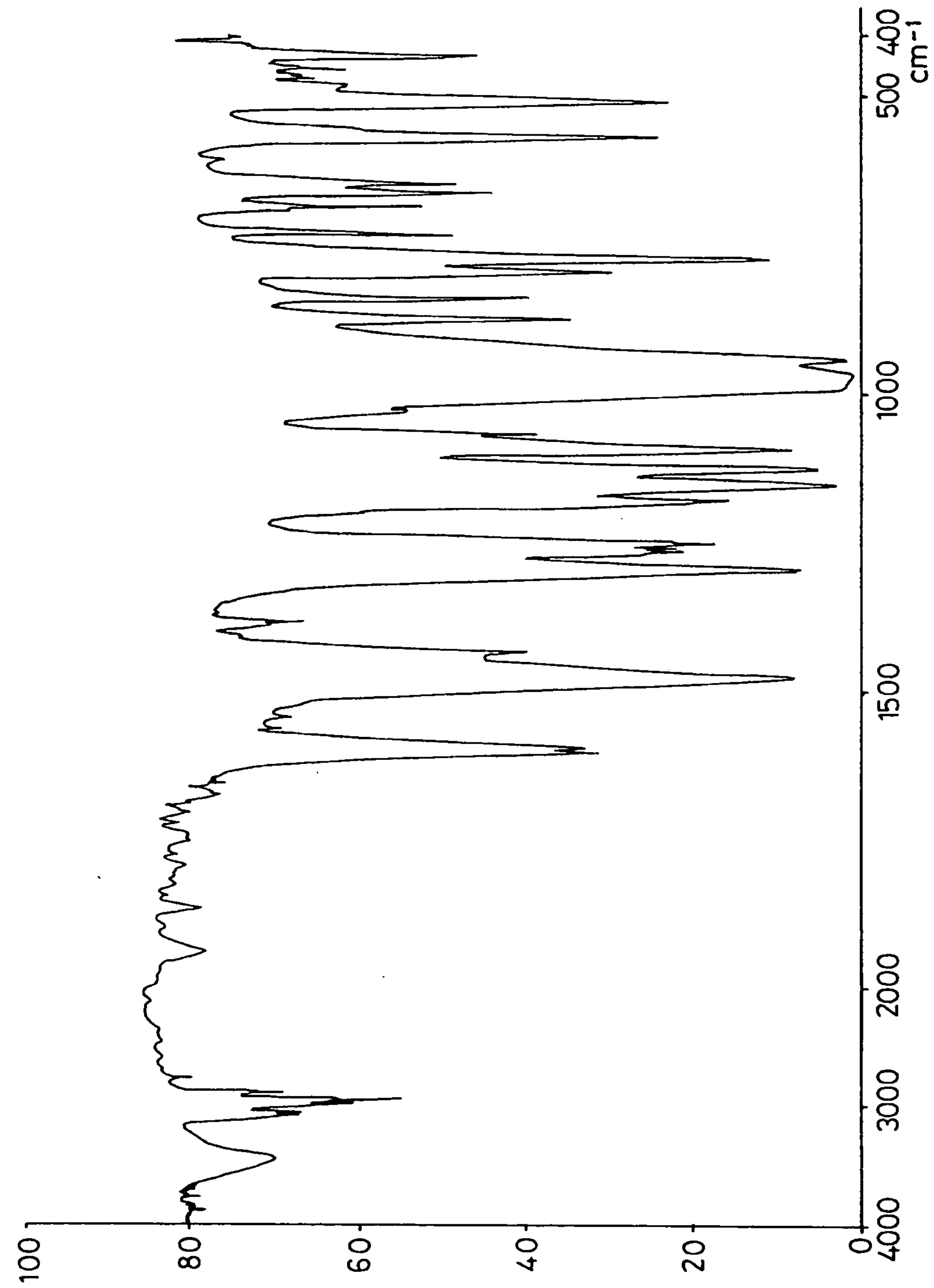


FIG. 2

Compound 2



F I G. 3

Compound 3